is unimportant until the speed comes very near to the light velocity, but the mass becomes suddenly infinite or very great when the light velocity is attained.

I find it difficult to realise the full effect of this kind of increase of mass, that is to say, of mass intrinsically possessed by the moving body, and not accreted on it from outside stationary matter. The latter effect is familiar in raindrops and in viscosity of gases, and it tends to reduce relative motion; but no previous instance is known where the mass of the moving body rises because it is itself a function of velocity. It would seem that the momentum must increase, and must disturb the balance of forces holding the parts of the system together. In an extreme case it might happen that the lighter body would suddenly become the heavier, would behave as if it had encountered an obstacle, and would jerk the rest of the atom off; or, on the other hand, it might happen that the most rapidly moving portion itself, by reason of its sudden access of momentum, would break loose and proceed tangentially. In any case it appears likely that an atom at this stage would begin to break up, as observed experimentally by Rutherford and Soddy; in other words, the fact of electronic radiation seems to carry with it the liability to change or decay of all matter possessing an electric constitution; the change from one form to another being accompanied, as they demonstrate in many cases, by radio-activity—a phenomenon which Strutt finds widely diffused.

It is hardly necessary to direct attention to a sort of astronomical analogy to this, though governed by different forces, in the contracting or gradual collapsing of a nebula, with the occasional shrinking off of peripheral material as an unstable stage is periodically reached, in accordance with the rough approximation known as Bode's law, together with the strong radioactivity of the central mass, and the conversion of constitutional potential energy into heat.

A few more words on the increase of mass at the critical velocity:—The only expression for mass as depending on velocity which has met with any attempt at experimental verification, is the expression of Abraham supposed to be verified by Kaufmann by direct experiment on curvature of kathode rays. Taking this as a simple example of the kind of effect to be expected, viz.

$$\frac{m}{m_0} = \frac{3}{4\beta^2}\left(\frac{1+\beta^2}{2\beta}\log\frac{1+\beta}{1-\beta} - 1\right) \quad . \ . \ . \ . \ (5)$$

where β is the ratio u/v, the speed of an electric particle to that of light, and m_0 its ordinary purely electric mass for slow motions, we find that when an electron is moving with *half* the speed of light, its mass is only 1.12 times what it was when stationary. At *three-quarters* of the speed of light the mass ratio becomes 1·37, or little more than a third greater than its normal value. At *nine-tenths* of the light velocity the mass is still not doubled, being only 1.8 times m_0.

When within 1 per cent. of the light speed the mass is trebled, or, more exactly, multiplied by 3·28, and when within one part in a thousand of its limiting velocity, the mass is almost exactly quintupled.

For higher speeds, say within $1/n$th of the speed of light, or $u=(1-1/n)v$, n being great, the expression for the electric mass ratio simplifies to

$$m = \frac{3}{4}\left\{\log(2n-1) - 1\right\}m_0 \quad . \ . \ . \ . \ (6)$$

which ultimately is truly infinite, but for even excessive values of n is only moderately great.

It is notable how close to the velocity of light it is necessary to get before this effect becomes prominent; the instability must be expected to arrive sharply whenever the velocity of light is from any cause, *e.g.* perturbation or collision, attained by any moving electrically charged part of an atom. Assuming a Maxwell distribution of velocities and an average speed, for the internal atomic motions, it may be possible (as J. J. Thomson suggested in NATURE of April 30, p. 601) to calculate what percentage of a given number of atoms reach the unstable stage by this means, and so to make a theoretical estimate of the amount of radioactivity to be expected, and of the life of an atom. But the slight constant radiation-loss seems competent to bring about instability and decay irrespective of collisions, and therefore independently of any Maxwell-Boltzmann law.

OLIVER J. LODGE.

PHOTOGRAPHS OF SNOW CRYSTALS.

AT the beginning of last year (vol. lxv. p. 234) we summarised a paper contributed by Mr. W. A. Bentley to the U.S. *Monthly Weather Review* upon his photomicrographs of snow crystals. Mr. Bentley has made a study of the forms of snow crystals for more than twenty years, and has obtained a most valuable collection of photomicrographs taken with the object of discovering the connection between characteristic forms and particular meteorological conditions. During the winter of 1901–1902 a systematic record was secured by Mr. Bentley of a number of snow storms, and several good photomicrographs from each storm were obtained by him, more than two hundred pictures being added to his collection. The annual summary of the *Monthly Weather Review* for 1902 (vol. xxx. No. 13), which has just been received, contains reproductions of these photomicrographs and a paper by Mr. Bentley describing the various types of structure and the meteorological conditions prevailing at the time when they were produced. The paper contains an instructive account of snow crystals, and an analysis of the results of the studies carried on during the winter of 1901–1902. The interest of the pictures lies not merely in the fact that many of the forms photographed are very remarkable, but that they also represent, so far as possible, stages in the life-history of snowstorms, several pictures having been obtained of each storm, while at the same time a record was kept of the conditions of temperature, pressure, wind, cloud and position of storm from which the snow fell.

We print a few extracts from the contribution and reproduce several photomicrographs of exceptional interest from those given in the *Monthly Weather Review.*

> In general the data tend to confirm further the conclusions of all observers, that a more or less intimate connection exists between form and size of nuclei, and the altitude and temperature of the air in which the crystals form. There can be no longer any doubt that there is a general law of distribution of the various types of crystals throughout the different portions of a great storm. On this point the data secured, both by direct observation and by a study of the weather maps, are much more complete and satisfactory than has hitherto been published. This aspect of our study received special consideration, because it was thought to be most important.
>
> Snowstorms often cover a region of vast extent; crystallisation is going on within them over nearly the whole area, and therefore in regions that differ greatly among themselves as to temperature, humidity, air density, electrical conditions, &c. Moreover, the kind, number, dimensions, altitude and density of the clouds within those various regions differ so greatly one from another that the snow crystals emanating from each region furnish us rare opportunities for observing and studying the effects of each of these various conditions upon the forms.

The results arrived at by a study of the data secured during the four winters of 1898–99 to 1901–2, inclusive, in regard to the relative frequency of occurrences of the various types and the apparent connection between size and form and the air temperatures, agree in general with the results arrived at by many other meteorologists and observers, both in Europe and America, as set forth in the work "Schneekrystalle," by Dr. G. Hellmann, Berlin, 1893.

Doubtless the actual connection between forms and sizes of snow crystals and the temperature and density of the air is much more intimate than our present knowledge would indicate, because our studies are based on air temperatures at the earth's surface, instead of in the cloud strata where the snow crystals form. The temperature may often be mild at the earth's surface when the crystals are developing at high altitudes where the cold is intense, and such crystals should be classed with those deposited during extreme cold.

Structure of Snow Crystals.—The beautiful details, the lines, rods, flowery geometrical tracings and delicate symmetrically arranged shadings to be found within the interior portions of most of the more compact tabular crystals, and in less degree within the more open ones, have attracted the attention of nearly all observers who have studied snow crystals. That these interior details more or less perfectly outline preexisting forms must have been early recognised, yet the knowledge as to what they actually were remained long in obscurity, and a complete explanation of all of them is yet to be found. The investigations of Drs. Nordenskiold and G. Hellmann enable us to form a general conception as to their true character. These observers discovered that many of the lines, rods, and other configurations within the crystals, that add so much to the beauty of the forms, and which are so plainly revealed in the photomicrographs, are due to minute inclusions of air. This included air prevents a complete joining of the water molecules; the walls of the resultant air tubes cause the absorption and refraction of a part of the rays of light entering the crystal; hence, those portions appear darker by transmitted light than do the other portions. The softer and broader interior shadings may perhaps also be due, in whole or part, to the same cause, but if so, the corresponding inclusions of air must necessarily be much more attenuated and more widely diffused than in the former cases. We can only conjecture as to the manner in which these minute air tubes and blisters are formed. It may well be that some of them are the result of a sudden and simultaneous rushing together of water molecules around the crystal from all sides. This might result in the formation of closely contiguous parallel ledges, or laterally projecting outgrowths that are separated from each other during the initial impact by a narrow groove, or air space, but are soon bridged over by subsequent growth. Similar contiguous parallel growths occur frequently around the angles of very short columnar forms, and lend plausibility to this theory. Air spaces also exist within columnar forms, as noted by Hellmann and Nordenskiöld. They seem to occur within such forms as hollow cup-like extensions, projecting perpendicularly within them from each of the ends of the crystals.

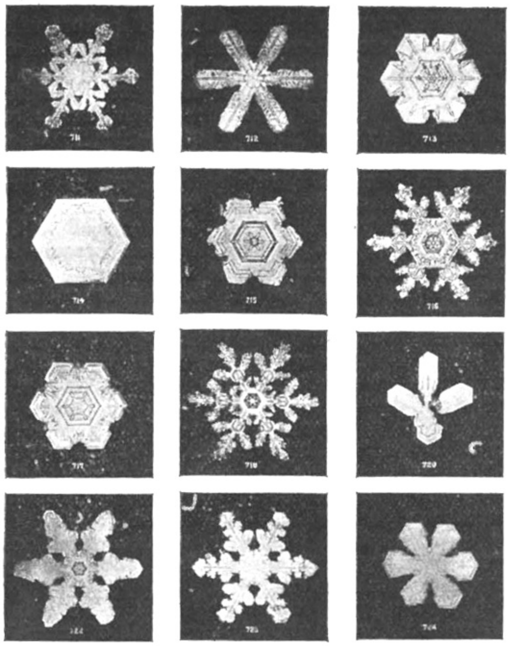

FIG. 1.—NOS. 711–724.

Modifications of Forms of Snow Crystals.—By close study of the photomicrographs, we find that the most common form outlined within the nuclear portions of the crystals is a simple star of six rays, a solid hexagon, and a circle. The subsequent additions assume a bewildering variety of shapes, each of which usually differs widely from the one that preceded it, and from the primitive nuclear form at its centre. Bearing in mind, however, the tendency of the crystals evolved within the upper clouds toward solidity, and the tendency of those from the lower clouds to form more branching open crystals, our task of deciphering the hieroglyphics, and of tracing thereby the probable flights of each individual crystal within the clouds, becomes much easier than might be anticipated.

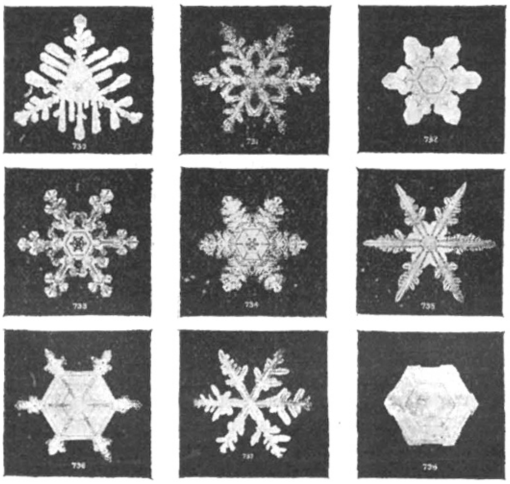

FIG. 2.—NOS. 730–738.

Taking photomicrograph No. 821 as an example, we can picture with some certainty its various flights within the clouds during each stage of its growth. Star-shaped at birth, it was probably carried upward by ascending air currents, and at some upper level assumed the solid hexagonal form that we see outlined around the star-shaped nucleus. Having now become heavier, it probably descended, and acquired further growth at some lower level, such as that wherein it had its birth.

Modifications of Forms due to other Causes.—As it is generally conceded that winds play an important part in modifying the forms of snow crystals, let us consider the probable manner in which they operate to accomplish this.

Aside from causing modifications by wafting the crystals upward and downward within the clouds to regions varying in temperature, humidity, density, &c., as previously noted, the winds probably cause modifications in other ways. Violent winds may prevent a perfect and orderly joining of the aqueous molecules, causing imperfections in the forms, or perhaps amorphous, granular aggregations.

Again, they may waft greater quantities of water molecules to one or more portions of a growing crystal, causing abnormal growth to take place around such portions.

More important still, violent winds often cause fractures to occur, especially as regards the branching forms, and whenever, as must often happen, subsequent growth takes place around and upon such broken crystals, irregular, unsymmetrical forms result. Doubtless, we may attribute the origin of some of the odd oblong crystals to the fact that crystallisation sometimes takes place around and upon a long broken branch, or other long portion detached by fracture from some preexisting crystal. Other odd forms seem to owe their abnormal character to design rather than accident. Columnar forms and, in a less degree, small solid tabular forms, being relatively so much heavier and more compact than stellar and similar branching forms, are much less likely than these to be wafted about and to receive modifications due to wind action.

Among the other causes of modification of forms, we must mention the close proximity of two or more crystals during one or more stages of their growth. This close proximity while developing would probably cause a greater growth of those portions of each contiguous crystal that lie farthest away from the crystal closely adjoining, and thus perfect symmetry would be impaired.

Considerable modifications of form are frequently due to the aggregation upon the crystals of amorphous or granular material, contributed by relatively coarse cloud spherules, particles of mist, or minute rain drops. Frail light, branching stellar and other forms are often rendered coarse and heavy by such additions taking place around and upon every angle of the crystals, so that they fall quickly to the earth.

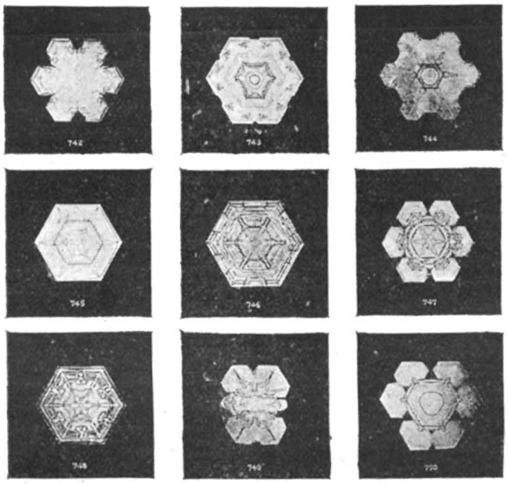

FIG. 3.—Nos. 742–750.

Perfect crystals are frequently covered over and lines of beauty obliterated by such granular coatings. Granulation often proceeds to such a degree, and the true crystals are so deeply coated over and imbedded within it, that the character of the nucleus does not reveal itself, except under the closest examination. Such heavy granular covered crystals possess great interest for many reasons; they show when the character of the snow is due to the aggregation of relatively coarse cloud particles, or minute rain drops, and not to the aggregation of the much smaller molecules of water, presumably floating freely about between them. They also offer a complete explanation of the formation and growth of the very large rain drops that often fall from thunderclouds and other rainstorms, if we accept the conclusion that such large drops result from the melting, or merging together, of one or more of the large granular crystals. For many reasons (among which we mention the almost invariable presence of low cloud strata when granulation occurs, and the aggregation occurring on perfect crystals, while these are presumably within the low clouds, rather than the occurrence of such aggregations as a distinct identity by itself) we are led to infer that, as a rule, the heavy granular covered crystals are peculiarly a product of the lower or intermediate cloud strata.

Chronological List of Snowstorms and Photomicrographs.—We now pass to the analysis of the photomicrographs of individual snow crystals secured during the remarkably favourable winter of 1901–2. The number of individual crystals is very considerable, and the beautiful or odd and interesting ones form a large percentage of the whole number; many of them deserve special mention and prolonged close study. Considering them in chronological order, the snow forms of the blizzards of November, 1901, first demand our attention.

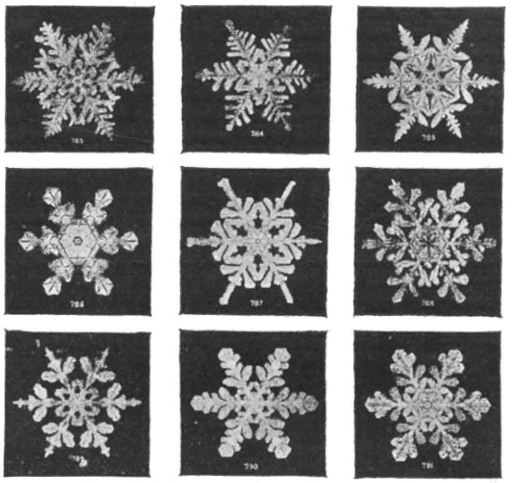

FIG. 4.—Nos. 783–791.

1901, *November* 26.—Eighteen different forms were photographed on this date, and among them two, Nos. 716 and 718 (Fig. 1), are very choice and beautiful. These exhibit a rather unusual and notable peculiarity, viz. a plain or delicately lined nucleus contrasted with a brecciated, boldly designed external portion; the latter approaching granulation, as though the nuclear portion was formed in clouds that were less dense and humid than those in which the outline portions were added. No. 712 is a fine example of the star-shaped form of crystal, exhibiting an extreme and slender development of the six primary rays without any corresponding development of the secondary rays. Many of the branching forms of this date were observed to be broken, as though by the action of violent winds.

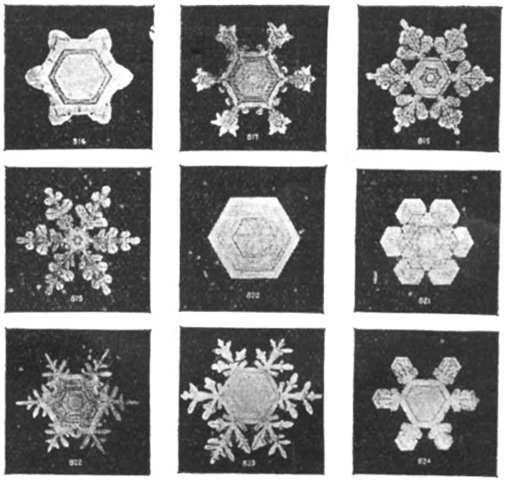

FIG 5 —Nos. 816–824.

November 27.—Continuation of the same storm. Crystal types small, granular, and irregular, succeeded later by medium-sized, rather compact crystalline tabular forms and a few doublets. Nos. 722 and 723 are charming patterns in snow architecture.

November 30.—Clouds rather thin stratus and nimbus. Crystal types wholly tabular of both open and stellate structure (Fig. 2, Nos. 730–737).

Among the seven forms of this date we find much to admire in the perfect beauty and symmetry of Nos. 731–734. The beautiful starfish design exhibited by No. 735 is somewhat rare. It is noteworthy that Prof. S. Squinabol, of the University of Padua, made drawings of a snow crystal found in Genoa in 1887 that closely resembles this latter one. The star with long slender rays deposited during this same storm, on November 26 (see No. 712), also closely resembles one figured by Squinabol in his work "La Navigata." No. 737 is another form that closely resembles some of those secured by other observers; it is very similar to some of the photomicrographs secured by Dr. Neuhaus, of Berlin, during the winter of 1893, and published in Dr. G. Hellmann's work.

December 4.—Clouds stratus, with detached running masses of low nimbus; probably high cirro-stratus above these. The western portion of this cold southern storm furnished a great number of forms of snow crystals that were in general rather small and compact.

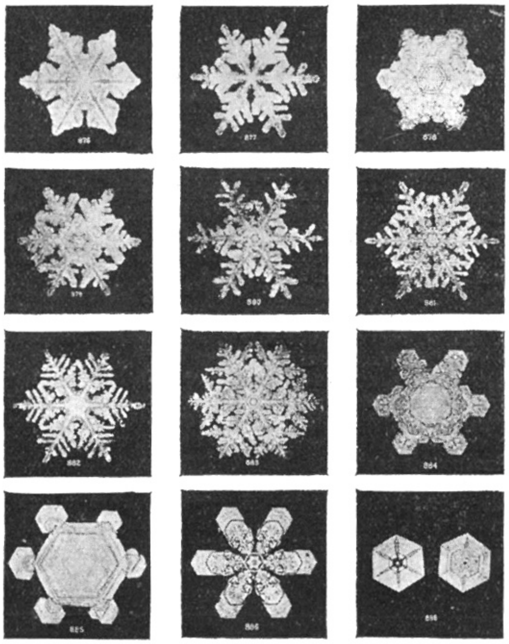

FIG. 6.—Nos. 876–888.

The rare beauty of Nos. 745, 748 (Fig. 3) will appeal to all; crystallographers will find much of interest in No. 749.

1902, *January* 5.—The clouds of the western edge of the storm of January 5, 1902, furnished a large and splendid set of forms. Nos. 783, 785, 786, and 788 (Fig. 4) are exquisite examples of the frail, branching type of crystals. No. 785 is so rarely beautiful that Mr. Bentley describes it as the peer of any in his whole collection.

January 12.—Clouds obscured by heavy snowfall. A long series of magnificent snow crystals was secured from the clouds of the south-west-central portion of the storm or blizzard of January 12 (see Nos. 816–824, Fig. 5). The snow, as usual whenever it comes from the central-western portion of a storm, consisted of a great variety of types both columnar and tabular, but as the storm's central portion passed farther to the east, during the afternoon of January 12, the columnar forms ceased to be deposited. Nos. 818, 821 and 822 possess much beauty of design and perfection of form.

February 8.—Clouds stratus and nimbus; probably high cirro-stratus superimposed above them. A continuation of the storm of February 7, and its increase in rigour furnished more forms than were ever before secured by Mr. Bentley from any one storm. The beautiful branching crystals, Nos. 881 and 883 (Fig. 6), portray, in general, the characters of the forms that successively replaced both the solid tabular and columnar forms, as the western edge of the storm came nearer. No. 884 exhibits a most interesting phase of crystallic evolution; it is composed of four contiguous points, or rather portions, and two somewhat stunted portions, also similar to each other, but differing widely from the other four. No. 885 shows two overlapping additions to two of the points, thus rendering it of more than usual interest, and presenting us with another seemingly unsolvable problem in crystallography.

In concluding this mention of individual forms, it is worthy of note that, as during previous winters, occasionally single individual crystals, and more rarely larger numbers of such, produced during the storms of this winter, resembled closely, in outline or interior details, or oddity, one or more of the individual forms found among the snows of previous winters. The recurrence of similar types, after perhaps long intervals of time have elapsed, is a phenomenon of great interest.

In conclusion, it may be worth noting that by the addition of more than 200 plates during the past winter, the number of individual photomicrographs of crystals in Mr. Bentley's collection is brought up to somewhat more than 1000, no two of which are alike. This completes also his seventeenth year of photographic work among the snow crystals.

DR. A. A. COMMON, F.R.S.

IT was with deep regret that the news of the sudden death of Dr. Common had to be announced in the last number of this Journal. Dr. Common was so hale and hearty that it came as a great shock to his friends to find that he was no more, and his loss is felt not only by a great circle of friends, but by the astronomical world at large. Born in 1841, August 7, Dr. Andrew Ainslie Common was by profession an engineer, but quite at an early date he turned his attention to astronomy. In 1874 he became the possessor of a 5½-inch refractor, and three years later of an 18-inch reflector by Calver. It was evidently the use of the latter instrument which sowed the seed for his later important researches in the making and silvering of both large and small mirrors. An idea of his remarkable energy and success in the grinding and silvering of mirrors can be gathered from the following list of large reflectors in use which he referred to in his presidential address to Section A (Department of Astronomy) of the British Association in 1900. This list only referred to reflectors of 2ft. 6in. and upwards, and out of the nine given five were from his own workshop.

Reflectors of 2 ft. 6 in. and upwards.

	ft.	in.
Lord Rosse	6	0
Dr. Common	5	0
Melbourne	4	0
Paris	4	0
Meudon	3	3
Solar Physics Observatory (Common) ...	3	0
Crossley (Lick; Common)	3	0
Greenwich (Common)	2	6
Solar Physics Observatory (Common) ...	2	6

His knowledge of engineering was a valuable adjunct in the designing and construction of the mountings for his large mirrors. Dr. Common paid great attention to this latter question, for on it depended to a very great extent their efficiency and utilisation. He eliminated the "tube" by substituting a light framework of iron which reduced air currents to a minimum; adopted a new method to prevent the mirror being strained; mounted large mirrors equatorially by the ingenious device of reducing the friction of the moving parts by floating them in mercury; designed